AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

IBM'S TOKEN-RING LAN -- A BASE-LEVEL COMMUNICATIONS SOLUTION

MAJOR J.D. WELLS 84-2765

"insights into tomorrow"

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Reviews the computer revolution and information explosion within the Air Force and their part in increased data communications requirements. Investigate the local-area network topologies for capabilities and characteristics that are advantageous in a CONUS, non-secure, base-level configuration. ~~Concentrates on~~ the bus and ring topologies. Then a closer examination is made of a hybrid star-ring LAN utilizing a token-access control mechanism. This LAN, as proposed by IBM, is seen to have superior maintainability, reliability, and flexibility.

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PREFACE

In an area of emerging technologies there is a tendency to buy the first thing that works. Two of the reasons for this tendency are inadequate knowledge and becoming enamored with a specific technology. Local-area networks are an emerging technology and it appears to me that there is an unjustifiable tendency within the Air Force to jump on the bus topology "bandwagon." This paper tries to dispel the notion that there is inadequate knowledge to make a considered choice by answering the question --Can an opposing topology better meet Air Force requirements?

There will be no attempt to address the performance question nor to cover security issues in this paper because both are adequately dealt with in technical journals and articles elsewhere. Rather, existing requirements and capabilities will be the deciding factors in my considerations.

This paper is intended for use by both the technician and manager alike. However, they are assumed to be data processing or communications professionals with five to ten years experience. The technician can use it to gain an appreciation for the importance of criteria other than cable bandwidth and the manager to gain an appreciation for the magnitude of the underlying requirement.

ABOUT THE AUTHOR

Major J. D. Wells graduated with distinction from Purdue University with a Bachelor of Science Degree in Industrial Engineering. He is nearing completion of a Masters of Public Administration degree from Auburn University. He has also completed Squadron Officers School and an Education with Industry assignment with the Federal Computer Performance, Evaluation, and Simulation Center.

Major Wells' assignments have been in both the enlisted and commissioned ranks. While enlisted, he served as a computer operator at base level and as a systems programmer at major command level. His commissioned assignments began at Headquarters, Strategic Air Command programming computer systems supporting the Joint Strategic Target Planning System. His most recent assignment was a Chief, White House Management Systems with the White House Communications Agency providing automated support to senior White House staff and the National Security Council.

While at the White House, Major Wells also served as a Presidential Trip Officer responsible for establishing radio, telephonic, and digital communications systems for use by the National Command Authorities. In addition, he had to plan and install audio-visual systems for use during Presidential speaking engagements. He has also participated in numerous presentations at national computer conferences.

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"insights into tomorrow"

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TITLE IBM'S TOKEN-RING LAN--A BASE-LEVEL COMMUNICATIONS SOLUTION

I. Purpose: To establish the feasibility of IBM's hybrid star-ring local-area network (LAN), using token-access control, as a candidate for the telecommunications vehicle at base-level for CONUS non-secure data communications requirements.

II. Problem: Although local-area networks have been discussed in technical journals and conferences there seems to be a lack of consideration for any selection criteria other than speed or performance. In the Air Force context other criteria are probably more important and should be given proper consideration. Maintainability, reliability, flexibility, and control are criteria that must be considered when choosing an electrical system that will be maintained and used by "blue suiters."

III. Data: Computers are becoming pervasive throughout all Air Force functions and mission elements. This increased use of computers has led to an information explosion and with it a parallel and just as significant requirement to transport data between users and/or their computers. Past failures to use a systems analysis approach to data communications requirements and the growing complexity and numbers of systems have rendered commercial carrier (telephone) systems inadquate or inappropriate to meet existing and future Air Force requirements. Pressing and accelerating forces for change in the data processing arena are present and they are affecting the ability of base-level data communications systems to meet the challenge. Concensus exists in

CONTINUED

both the data processing and communications fields that local-area networks are the solution. However, there has been a tendency to focus on the "bus" topology without an adequate review of the other topologies. The "mesh" and "star" topologies are too expensive relative to the "bus" and "ring" topologies. Network expandability, reliability, and performance are a function of the network topology or structure. Since bus topologies are more susceptable to single component outages and the ring topology has inherent modularity and flexibility, a form of the ring topology is more maintainable. IBM has proposed a hybrid of the star and ring topologies that offers the advantages of both while overcoming the disadvantages. The hardware components of this configuration, using wiring concentrators, bridges, and gateways, provide the flexibility, reliability, configurability, and interoperability needed by any Air Force installation. The token-access scheme provides the control and predictability needed in any military system that may have to support precedences.

IV. Conclusions: The pervasive use of computers have placed increased demands on the Air Force's base-level data communications systems. Their base-level data communications systems must be dynamic enough to handle future Air Force requirements.

V. Recommendations: The Air Force should install a hybrid star-ring LAN as proposed by IBM for comparison with the current prototype bus LAN being installed at Gunter AFS, Alabama.

CHAPTER I

INTRODUCTION

Envision if you will, the following conversation between a pilot and his crewchief:

> "Sergeant Jones, have all the problems with that w--rning light from yesterday's flight been corrected?" ' .., Sir. After your debriefing, I used the BIT/FIT circui y to isolate the problem to a bad board in the fire c .trol computer." "Sergeant, are you saying it was an er hardware problem?" "No, Sir, I'm not. The sof inside the imbedded computer was at fault."

At first glance you would expect this exchange to occur surrounding the Advanced Tactical Fighter on a flightline of the future. But I submit that it could happen today on any flightline with deployed F-15 aircraft. However, the mere fact that we're using advanced computer technology in today's fighter is not the most surprising element of this conversation. It's the conversational use and understanding of computer terminology (i.e., hardware and software) by the pilot. There is hardly any area of Air Force life that has not been affected by the "computer revolution." The effective use of computers requires a basic understanding of their component parts and their applicability to Air Force mission elements. Even most pilots understand computer "buzzwords." This is a change from just a few years ago when the "buzzwords" were left to the computer professionals.

INFORMATION EXPLOSION

The world is changing around us. This change is being led by the increasing use of electronics and in particular, computers. Also, our working environment is being populated by increasingly complex systems. And they all seem to have a computer inside them. Computers are data "processing" machines. Literally, they input data, process it, and output information (processed data). This increased use of computers and their concurrent use and generation of large amounts of data have led to the coining of the phrase "information explosion."

DATA MOVEMENT

This information explosion has caused an increased requirement to transfer data from one location to another. In the Air Force there are four basic reasons why data are transferred. First, we are beset by a host of reporting and coordinating requirements. We are required to report information to higher headquarters units. This information is usually in the form of summary information for executive level consumption, or it may be raw or bulk data if we are part of an organization that exercises centralized control of our activity. The necessity to keep sister units of an organization informed of your activity also generates data transfer requirements. Coordinating or sharing of information requires that we transfer it to organizations with only peripheral interest in our actions.

Secondly, there may be economic or functional reasons for transferring data between organizations. It may cost less to have two smaller computers processing separate sets of data than to configure one that is more complex to process both sets simultaneously. However, even if the data are processed separately, there may be (as is often the case) a relationship that requires their combination in some other process. For example, consider a TAC maintenance unit that keeps track of all its aircraft that are not mission capable because of supply (NMCS) and the supply system that tracks priority requests. These two pieces of information are required inputs to the force status information maintained by the wing commander's staff.

The third requirement to transfer data may be mission related. That is, survivability or maintainability may be the driving force behind the requirement to transfer data. One way to make a system more survivable is to "break" it up into smaller systems that are connected by a data distribution system. This is "distributed processing" in its simplest form. The idea behind this concept relies on the fact that the entire system is not lost because of the failure of any single component. This same concept also aids in making complex computer systems more maintainable. For example, it is easier and cheaper to replace one of five semi-independent components than to replace a more complex single system that integrates all five components.

The fourth reason that requires the transfer of data is geography. The physical separation of producers of data and the consumers of that data necessitates the movement from one location to another. Other than purely data processing factors may require that a unit split its operation into separate groups. For instance, lack of office space may place parts of the same unit on opposite sides of the base or at best on different floors of the same building. Also the number of users of computing systems are increasing. They are frequently connected to a central facility by remote access. This remoteness requires that some distribution system be established to transfer the data and/or information to and from the users and the computer.

These four reasons for data transfer, coupled with the information explosion, are resulting in an exploding data transfer requirement. Data transfer (hereafter referred to as data communication) solutions are the main thrust of this paper. Particular emphasis is placed on recent innovations and enhancements to a technique that was thought to be inappropriate to the Air Force environment. I will attempt to answer the question of whether the token-ring local-area network (LAN) as proposed by International Business Machines Corporation (IBM) can feasibly meet the CONUS, non-secure, base-level data communications requirements of the Air Force. I will do this by first investigating the forces for change on base-level data communication. Because military systems have special requirements, they will be reviewed in light of the base-level data communications environment. Next, I will review and discuss LAN characteristics in general and IBM's implementation in particular. Finally, I will make a qualitative determination of the token-ring LAN to meet Air Force requirements.

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CHAPTER II

DATA COMMUNICATION REQUIREMENTS

In the telecommunication area requirements are traditionally grouped functionally into "communities of interests." The two communities of interest are command and control and all other communications. For this analysis we will further group communications into inter-base and intra-base communications requirements. The Defense Data Network (DDN) is DOD's future solution to inter-base communications requirements and will only be addressed here insofar as it impacts the interoperability, interface requirements, and performance characteristics of intra-base systems.

> . . . Until the introduction of third generation ADP systems in the 1964-65 time frame, the requirement for data communication support was nominal. Most ADP systems operated in a "stand-alone" manner, supporting users in a batch processing mode to provide "over-the-counter" service at the [central] ADP center. Data exchange between ADP centers was typically by mail, a dedicated circuit, or by AUTODIN I. During this period little attention was given to the total systems aspects in the design of automated systems, nor was the ADP technology available to support a systems approach. (8:20-21)

SYSTEMS APPROACH

There have been a number of attempts to remedy this lack of a systems approach to meeting Air Force Data communication requirements. At the request of Headquarters, Air Forc Systems Command, Electronic Systems Division (ESD) conducted ae mission analysis "to define the needs and objectives of Air Force Base communications and information transfer systems." (7:iii) This base communications mission analysis (BCMA) was completed in 1973 and had as one of its major findings "the present system in base communications, administrative services, and data automation does not satisfy user needs." (7:3) A more recent Base Support Communications Programs (BSCP), conducted under Annex 81-1 of a formal Memorandum of Agreement between ESD and the Air Force Communication Command (AFCC), had as its objective "to develop a comprehensive and cost-effective base communications plan that satisfied the requirements of base level support functions through the 1980's and into the 1990's." (4:11) The approach of these two studies was to assess requirements relative to existing services provided.

A more recent Base Information Services Master Plan: Strategic Plan developed by the Air Force Data Systems Design Center (AFDSDC) states that

> Dependency on information systems is increasing very rapidly for two reasons. First, Air Force missions, organizations, processes, tasks, weapon systems, and technologies are growing increasingly complex. Second, the growth in the complexity of day-to-day Air Force operations requires that managers and operating personnel have access to more and better information -- about a wider range of issues. The only practical way to deal with this "information explosion" is to employ effective information system. (6:1)

However, a closer examination of the forces for change is appropriate to understanding the Air Force data communications requirements.

FORCES FOR CHANGE

There are five broad forces for change operating within the Air Force environment. They are growth of new applications, interactive and computer-to-computer applications, bulk data transfer, stimulation of new requirements, and increased demand for existing service. (8:20-21) The first of these -- growth of new applications -- is primarily a result of the advances in computer technology and the drastic reduction in cost of these systems.

> This [micro-miniaturization] yields faster more powerful systems consuming less energy whose price/performance ratios are constantly decreasing. For the last twenty years, an exponential law (Moores's Law) has described the increasing density of components on chips. It predicts the average chip component density to double every year. (6:13)

Figure 2-1 depicts this trend graphically. Figure 2-2 illustrates the trend for commercial ADP system life-cycle costs. One can easily visualize that the DOD curves will be close if not the same as these. The combined impact of more powerful and smaller systems, coupled with cheaper hardware cost, decreases the cost of entering the computer field and increases the area of feasible computer applications. That is, new applications and requirements will continue to grow.

The second force for change is interactive and computer-to-computer applications. As our computer systems become faster and more powerful, the number and frequency of

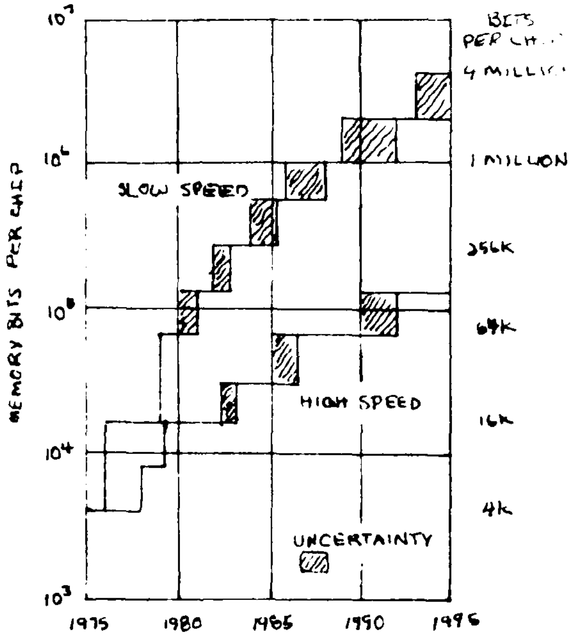

FIGURE 2-1: Bit Size of Semiconductor Memory Chips (6:14)

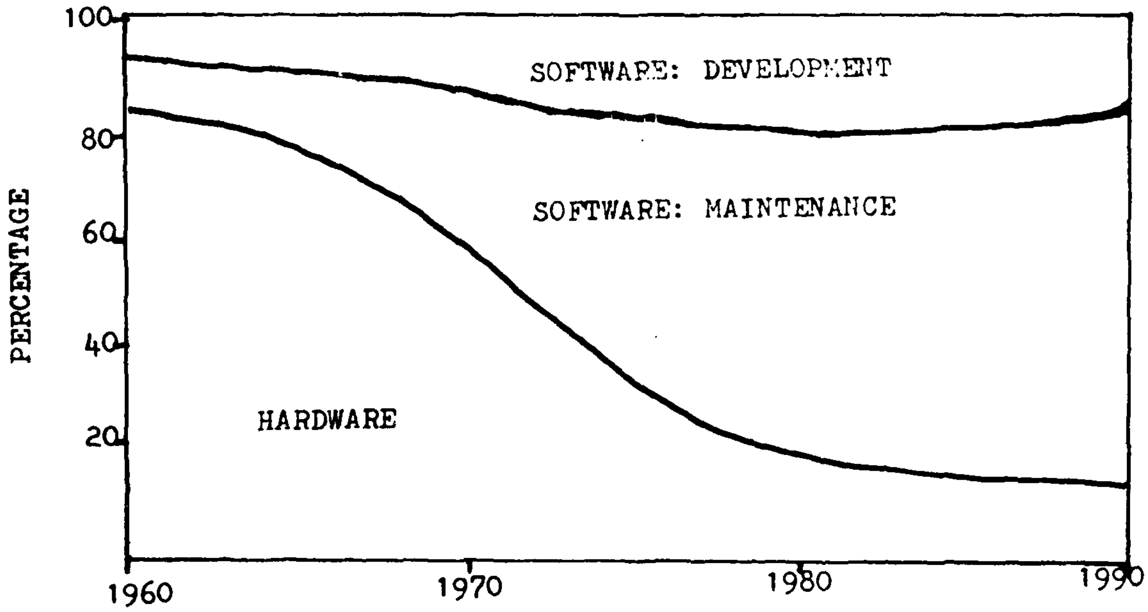

FIGURE 2-2: Life-Cycle Costs of ADP Systems (9:158)

applications that are interactive will increase. Interactive or "on-line" systems have continued to replace those batch systems of the 1960's. A result of one Air Force requirements study predicts upwards of 2000 terminals will be required at large bases such as AFLC Air Logistics Centers. (4:42) Computer-to-computer data communications is growing. As the number of distributed systems increases so will the computer-to-computer data transfer requirements. But existing central computer systems will continue to affect computer-to-computer systems because "frequently, data from one computer is required to update a data base or display residing at another location." (8:21)

Bulk transfer applications is the third force for change within the Air Force data communications environment. In many older systems there was no easy way to accommodate voluminous or bulk data transfer using telecommunications techniques so customers had to be satisfied with physical distribution. This was usually done by mail or carrier systems. "As more customers developed more applications requiring bulk data transfer, some concessions were made in existing systems to satisfy those needs." (8:21)

The fourth force for change in data communication is stimulation of new requirements. The success of a computer application generally increases demand for similar services in other functional areas. For example, the Air Force is already experiencing moderate demand for electronic mail services. "The great advances in technology and the application of those advances will continue to create demands for services that do not presently exist." (8:21)

The fifth and last force for change is increased demand for existing services. Though the Air Force continues to consolidate existing facilities, such as the Phase IV program, increased demands continue to be made for new locations and for increasing the number of terminals at existing locations.

All of the aforementioned forces for change place increased demands on the data distribution systems of the typical Air Force base. These forces for change are general in nature and apply equally across all Air Force functional elements. That is, these forces are equally at work in Civil Engineering (CE) and Base Supply. In the past CE has been a low consumer of ADP services while Base Supply has been a large consumer. While the general forces are important for assessing the data communications requirements, a look at some of the more significant detail impacts is necessary for a full appreciation of the magnitude of the requirement for change.

OTHER IMPACTS

The Paperwork Reduction Act of 1980 is a very significant factor in the growth of data communications requirements. (6:20) First of all it is the "law of the land" and cannot be ignored or bypassed. It also has merit. In spite of the fact that we have large bureaucratic systems, Americans generally have an aversion for the needless paperwork that is required of us. However, most of the paperwork in existence has a functional requirement or basis in statute or regulation. A solution to this problem is to capture the data at the source and dispense with the paper by placing an interactive terminal at the point of data capture. For example, a majority of the paperwork involved in Air Force personnel records could be eliminated if a terminal were given to each Customer Service clerk in CBPO. This ignores such legalities as signatures, but advances are being made, and the Paperwork Reduction Act is providing a constant push for change.

Office automation will be a major drive in the direction of future base-level data communications.

> [It] is becoming a reality for increasing numbers of organizations. Office automation is helping these organizations to improve the productivity and effectiveness of office workers and to improve the timeliness and accuracy of the information on which they depend. (1:1-3)

Most information flow at base-level is not electronic and therefore outside the base data communications system. It is reasonable to believe that most of this flow (letters, forms, manuals, or face-to-face conversation) would be handled electronically. (7:8) Telephone and face-to-face conversation are giving way to computer assisted message and conferencing systems. Air Force weapon systems, under the "come-as-you-are" concept, are planning to take technical order manuals to the weapon system on hand-held displays. Data automation throughout the Air Force is happening sooner than we realize.

Probably the most significant impact will come from personal computers.

> The International Data Corporation projects that in 1986 U.S. desktop computer shipments totaling $14.2 billion will exceed U.S. mainframe shipments of $13.7 billion. This astonishing projection exemplified both the nature and rapidity of change in both public and private organizations. (3:24)

In an attempt to get this situation under control, the Air Force has gone out on contract with a buy of 8,000 "standard" personal computer systems. Though the exact nature of this impact on data communications requirements is unquantifiable at this point, there is general concensus that its magnitude will be large.

RATE OF CHANGE

The pace of these changes is fast and is accelerating because of the combined pressure of advancing technology and increasing user acceptance and familiarity with computer systems.

> . . . The date communications facilities of the future cannot be all things to all customers; but enough flexibility must be incorporated in the facilities to provide acceptable services for the valid requirements of subscribers. (8:21)

> Present base support communications systems have not been designed for this purpose [support to potentially thousands of terminals]. Thus, changes are foreseen that may greatly alter the shape of base communications by the end of the 1980's. (4:12)

The thread that runs through the change and growth discussed above is "dynamics". Any base-level data communications systems must be dynamic enough to handle the pace of change and rate of growth of Air Force future requirements, or it would be violating the spirit of one of the major recommendations made by the National Research Council concerning the Air Force Phase IV upgrade -- "Grow and keep modern by evolutionary processes to avoid another major capital replacement." (5:8) In short, the base-level data communication system must be both flexible and extendable. It must also overcome the shortcomings of existing support.

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CHAPTER III

LAN CHARACTERISTICS

PAST PRACTICES

Since LANs, by their very nature, are geographically limited -- a single building, building complex, or Air Force base -- they are not constrained by the limitations and practices of the common-carrier provided facilities. Though the public telephone system is the primary supplier of data circuits between and among computer systems, it had its origin supporting less demanding voice transmissions. Therefore the maximum transmission rates and error rates of voice grade circuits, while more than adequate for voice transmissions, are severely limiting to data transmissions. For example, the transmission time of a high resolution graphics display would be unacceptably long at the 2400 bits-per-second rate of the telephone system. Also there is the present practice of routing all users through the telephone central office for control purposes. This applies even if two terminals in the same office are connected together. For this paper the base supplied telephone system is not distinguished from the commercial common-carriers.

> Today's network transmission technology permits the transfer of large blocks of data at these rates [many millions of bits per second] with simple error recovery procedures and control protocols. These transmission rates also permit a large number of data terminals to share the common physical interconnection link with a minimum of interference from one another. (2:47)

TOPOLOGY

There are four LAN topologies that are generally considered feasible -- the mesh, star, bus and ring. The first, the mesh topology, is possible but its high cost for dedicated lines or its complexity usually excludes it from consideration except when reliability or availability dictate its use. See Figure 3-1. In the second of these topologies, a star network, each network node accepting and delivering user traffic is connected to a single central node through which all traffic must pass. The central node acts as the system control and has separate communication lines to all other nodes. Note that the telephone system employs a star topology. For the third, network nodes connect to a single transmission medium to form what is termed the bus topology. Each node has an address used to uniquely identify the participating nodes. The bus is typically multiplexed allowing information to be transmitted in short, high-speed bursts. And lastly a ring network consists of nodes with connections only to the node on each side of itself, such that a complete circle is constructed. Data must pass through all nodes between the sender and receiver. A simplifying distinction for the latter three topologies is gained by considering each node of the star as having a dedicated transmission medium; each node of the bus is connected to the transmission medium; and each node of the ring is connected by the transmission medium.

The mesh and star topologies both use dedicated lines to connect each node to the network (the mesh is even more complex because each node is connected to all other nodes). Both of these topologies are extremely expensive relative to the bus and ring without a proportionate advantage in efficiency and will be dropped from further discussion. The bus and ring topologies, however, use a shared transmission medium to allow geographically dispersed (local area) nodes to communicate in an economical fashion. This gives the added advantage of having a nearby transmission medium to connect to as opposed to having to run a cable either back to the central controller (star) or to all other nodes (mesh).

RING VS. BUS

The topology of a network is a determinant of its expandability, reliability, and performance. The ease with which you can modify a network not only influences the time it takes to make a change but it also affects your willingness to expend the effort. The expandability gained as a result of ease of modification also enhances flexibility. Considering first the bus topology, the usual assessment of its expandability involves assessing only the ease with which you can add another node into the network. This approach is inadequate because it doesn't consider all possible situations. For example, figure 3-2 depicts the situation where a bus network provides support to three of four buildings with building D to be added to the network. Since the bus backbone must be a continuous high quality cable, additions in building D must be made by first extending the backbone cable from one of its terminated ends to building D. The Air Force doesn't and shouldn't let itself get into the situation where the location of a user's work area determines the responsiveness to his request for support. The topology of the bus network limits its expandability. Even more important, the physical construction of a bus network has limited modularity. This is counter to the evolutionary and flexibility requirements stated in the Base Information Services Master Plan. (6:7)

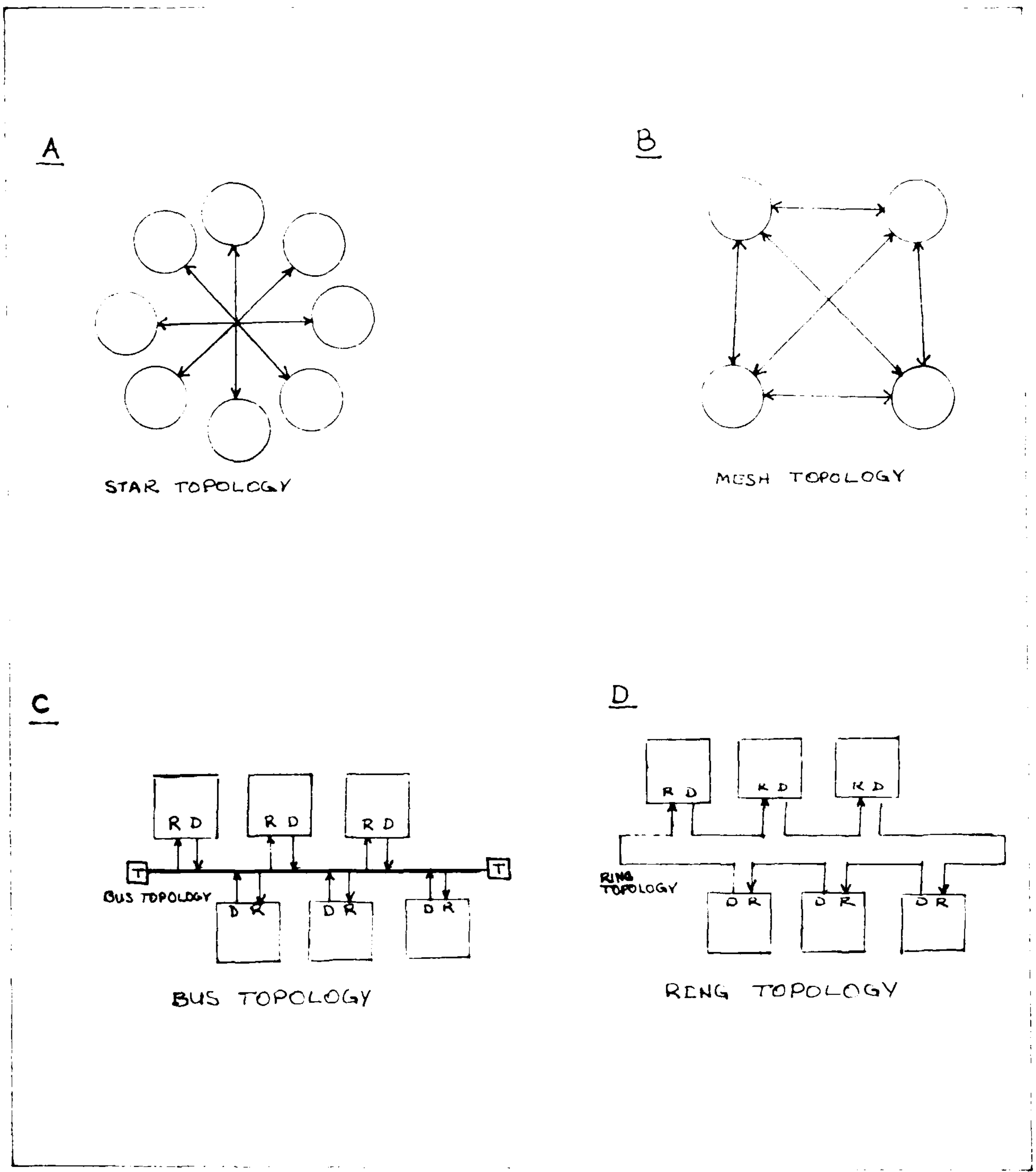

FIGURE 3-1: Local-area Network Topologies

If the same requirement for change (addition of support to building D) existed for a ring topology (figure 3-3), the process would be a lot easier to accomplish. Ring topologies are usually implemented in subnetworks and bridged together to form the complete network. Support would be added to building D by installing and testing the subnetwork and then bridging it to the nearest point in the existing network.

The physical topology can also affect reliability. Since the bus topology requires a physically continuous transmission medium, it is susceptable to total network outages when a single component fails. On the other hand, the ring network is composed of subnetworks that operate independently of one another. Therefore, the ring topology has inherently better reliability when a single component fails.

This same modularity and flexibility also could contribute to an advantage in performance for the ring topology over the bus topology. For example, the bus backbone cable must have uniform capacity along its entire length. A node transmitting in error could possibly saturate the backbone cable thus affecting all other nodes in the network. However, since the ring network has independently functioning subnetworks, erroneous transmissions would have only localized effect. That is, in Figure 3-3, a failing node in building A would not affect the nodes in building B, C, or D.

From a purely qualitative analysis, the ring topology provides more expandability, reliability, and performance options than the bus topology. These advantages are a direct result of the physical characteristics and, thus, the modularity and flexibility inherent in the subnetworks employed by a ring topology.

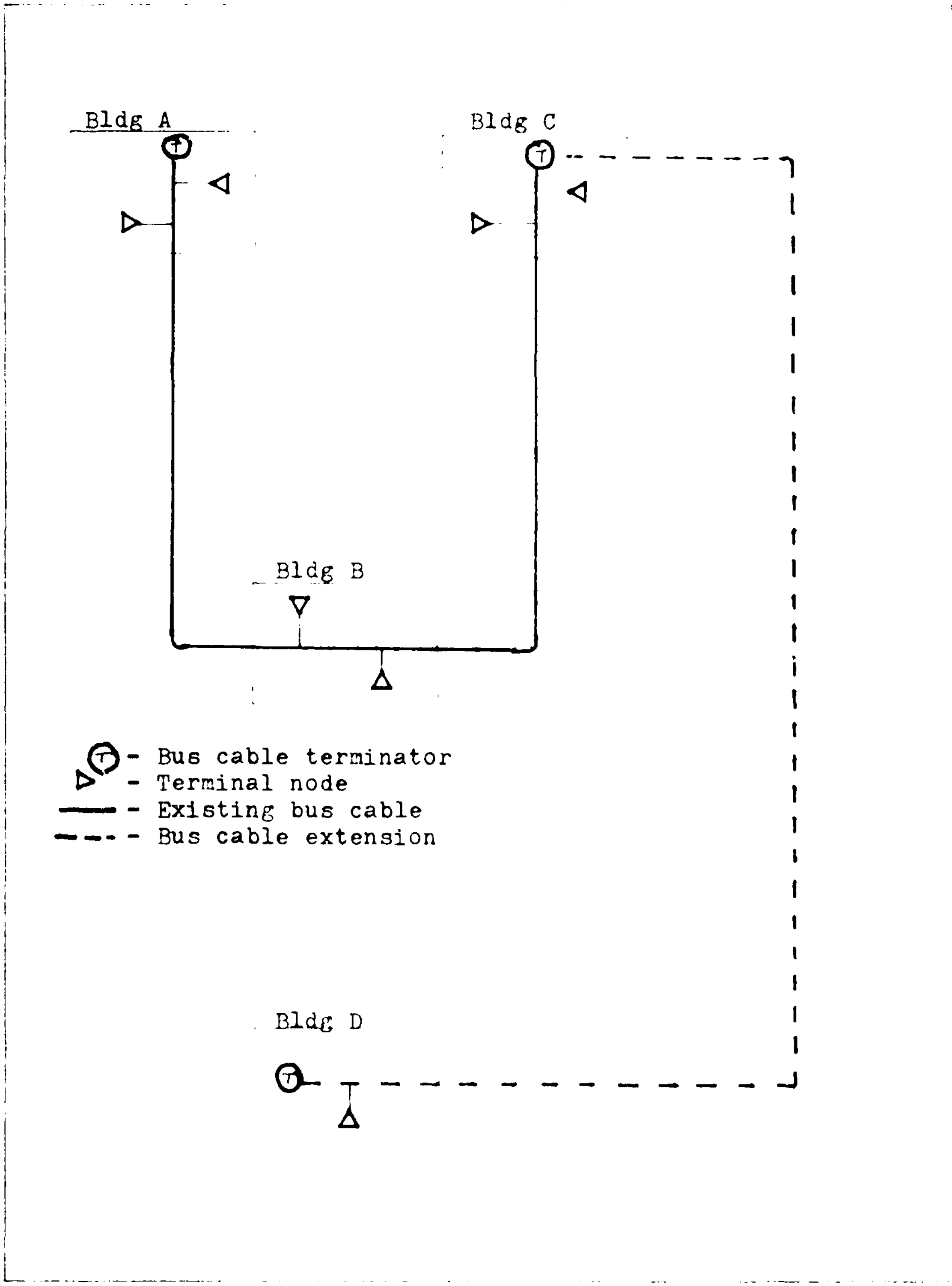

Figure 3-2: Adding Bus Topology Support to Another Building

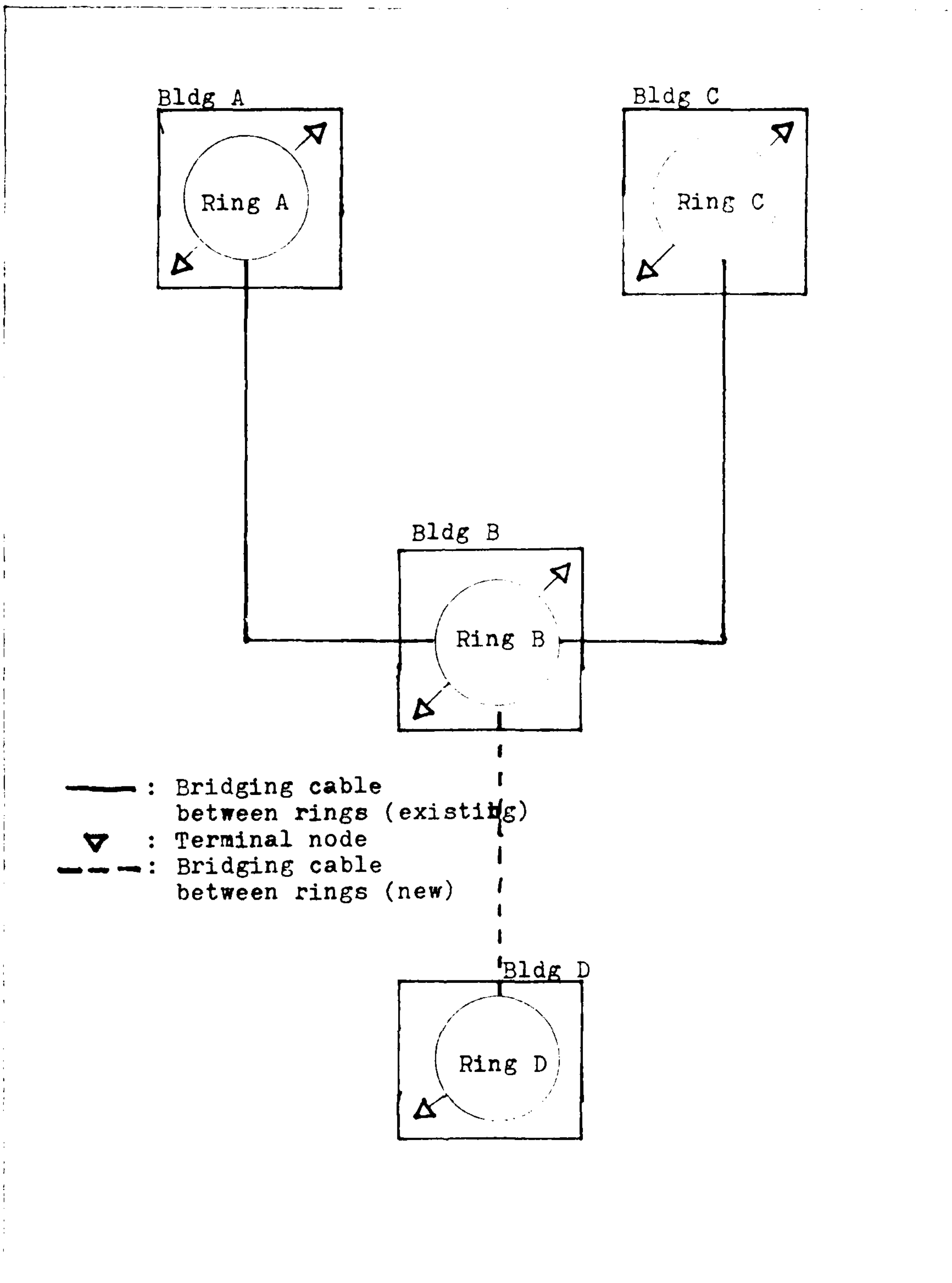

FIGURE 3-3: Adding Ring Topology Support to Another Building

CHAPTER IV

IBM's LAN OFFERING

Local area networks are expected to provide information transfer services at base-level as part of the data communications modernization strategy of the Base Information Services Master Plan. (6:27) For Air Force purposes, the primary objective of a LAN is to provide high-speed data transfer among a group of nodes consisting of data-processing terminals, controllers, or computers within the confines of a building or Air Force base environment. IBM has proposed a token-ring LAN that addresses some issues that are critical to Air Force requirements -- fault detection and isolation, as well as the aspects that allow for network expansion and growth. This chapter will describe a LAN based on a ring topology using token-access control that resulted from research by IBM at laboratories in Zurich, Switzerland and Research Triangle Park, North Carolina.

CONFIGURATION OBJECTIVES

The configuring of a LAN usually requires consideration of two main objectives. First, the overall length of cable should be kept as short as possible. Secondly,

> . . . concentration points should be provided in the network to facilitate cable installation and network configuration and maintenance. These two objectives are not independent and must be balanced to reach a single solution for a ring network. (2:49)

This balance between minimizing total cable length (to achieve low system cost and limit overall transmission distances) and maintenance and reconfiguration requirements is not readily handled by the classical LAN topologies. For example, a pure serial interconnection of nodes is best when minimizing cable lengths. However, the costs to maintain and reconfigure would be inordinately high for this arrangement. But, in order to achieve maximum flexibility for maintenance and reconfigurability, a pure star-radial cabling scheme, where all nodes are cabled to a single concentration point, overcomes these problems. What is needed is a solution that satisfies both main objectives.

THE STAR-RING HYBRID

The star-ring hierarchical topology combines the key advantages of both approaches. Major components of this system are shown in Figure 4-1. The nodes, wiring concentrators, bridges, and gateways are organized to form the composite local network. Computer workstations (nodes), connected to the network through a communications adapter, transmit information signals over the transmission media.

Wiring Concentrators

> Wiring concentrators provide a key element for structuring a system to provide both flexibility and reliability . . . Each node is attached to a single lobe of a wiring concentrator, with the lobes being physically connected within the concentrators to form a serial link. (2:50)

See Figure 4-1. The ring is completed by connecting the wiring concentrators in a serial fashion. This segmented wiring between wiring concentrators allows preplanned wiring, workstation movement, and intermixing of transmission media. This wiring scheme results in a highly flexible star-ring hierarchical configuration. Reliability is also enhanced because wiring concentrators provide convenient points for reconfiguration and maintenance of the network. "Switching elements exist within the wiring concentrators for bypassing each lobe selectively." (2:50) This lobe-bypass function may be controlled either manually, automatically, or remotely.

Bridge Operation

The operations of a ring network requires that the electrical signals be regenerated as they pass through each active node in the ring. This allows the network to span a large area since the signal does not have to be propagated between extreme points in the network, only to the next node. Note also that this allows the flexibility of using transmission media of appropriate quality and bandwith as opposed to a bus network wherein the tranmission media serving all nodes is usually a continuous cable(s) of uniform quality and bandwith. An extreme example is when a five megabit bus is extended to another building to provide access to the network for a single 2400 bit terminal. Theoretically, a ring network could be configured with an unlimited number of nodes. However, practical considerations, such as unwieldly network management, low-frequency jitter caused by a large number of repeaters (each node), and data capacity, limit the typical configuration to 100 to 200 nodes per ring.

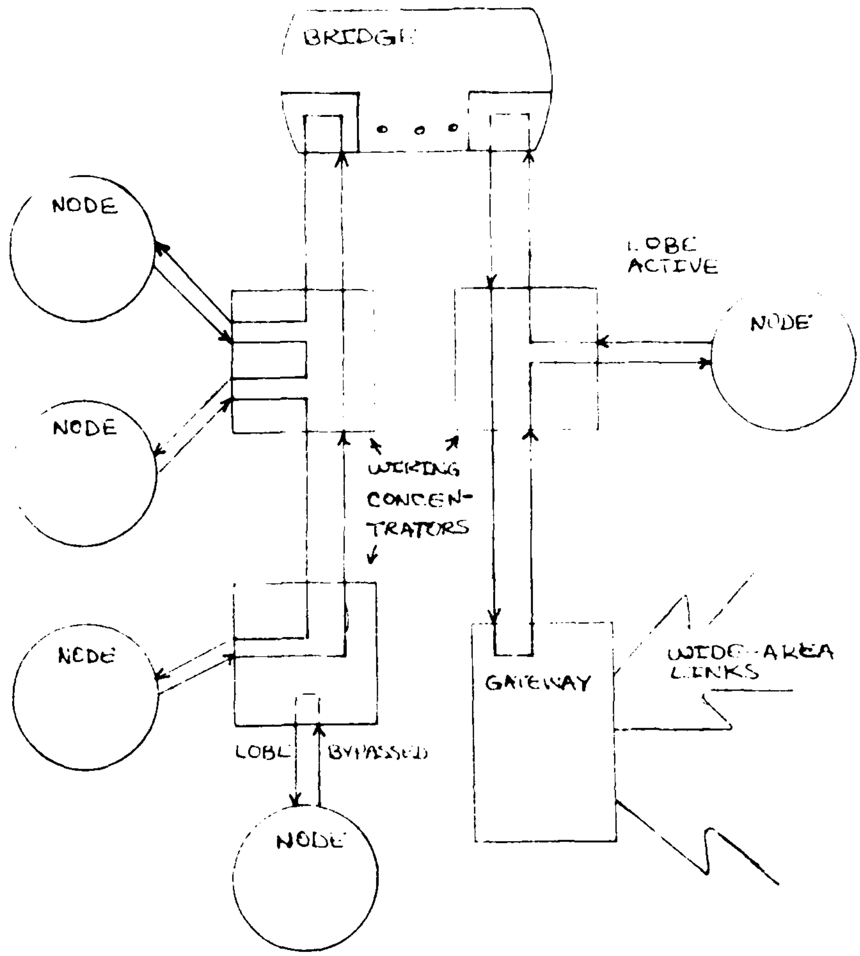

FIGURE 4-1: Wiring Topology and Components of a Ring Network (2:50)

A bridge can link multiple rings when the nodes are spread over a large area or when the capacity of a single ring is exceeded. The bridge is a high-speed digital switching mechanism that provides logical routing between rings. The routing is transparent to the attached nodes.

> Individual rings that are connected through the bridge operate autonomously and, therefore, may stand alone. This capability allows several independent rings to be installed and interconnected to form a larger LAN. The network can be further expanded by interconnecting multiple bridges. (2:50)

The flexibility and modularity afforded by this "building block" approach is unmatched by any other networking scheme. Contrast the amount of planning required to get a continuous-media bus cable to (1) all the buildings on a base, (2) all the floors of a building, and (3) all the areas of a floor. Add to this the serpentine nature of the resulting cable and you have a configuration management nightmare. The situation gets even more unappealing when support must be added for a new building to an existing bus network. The situation is quite different for a ring network. Rings are installed where initially needed (less tortuous and more flexible planning), and as new requirements arise they are independently "ringed" and "bridged" to the nearest ring in the existing network.

The bridge also functions as a speed converter when the bandwith (and speed) differs between rings.

> A very large installation [or Air Force base] could then be supported by many rings, all interconnected via a hierarchical network structure with a separate high-speed backbone link between bridges. The backbone itself may be a high-speed ring [Figure 4-2A] or it may be a bus network, such as a channel within a broadband cable television system [Figure 4-2B]. (2:51)

This arrangement requires that the rings and backbone use the same addressing structure that includes as part of the address both the ring designator and node on the ring.

Gateway Operation

Wide-area networks, such as AUTODIN, ARPANET, and DDN, provide long-distance (interbase) communication support and are accessed by nodes in the ring network through a gateway. These military wide-area networks as well as their commercial counterparts all operate in the kilobits-per-second transmission range. However, they all use different protocols and adhere to different standards.

A gateway can provide the speed and protocol conversion that are required to interface the LAN to these various transmission facilities. Thus nationwide or global communications among multiple LANs can be established. (2:51)

CONTROL MECHANISM

Token-Access Control

Permission to use the communications link in a ring is controlled by passing a token (unique electrical sequence) sequentially between each node around the ring (Figure 4-3). The token also contains an indication of whether it is free (available for use) or busy (in-use). Each node, in turn, has its chance to transmit data upon receipt of the free token. If a node has data to transmit, it seizes the free token, changes its status to busy, begins data transmission. The node that started the transmission of the data is also responsible for removing the data from the ring and changing the token (that precedes it on the ring) status back to free.

The bridge appears to each independently operating ring as a normal node and must recognize data frames destined for other rings. The bridge must then perform the appropriate routing. The primary functions associated with token recognition and data transmission are performed by a ring interface adapter at each node. This adapter handles the basic transmission functions including frame recognition, token generation, error checking, buffering of frames, and link fault detection.

FAULT DETECTION AND BYPASS

One of the major disadvantages of rings employing token-access control has been the problem of "lost" tokens. This has been solved, in IBM's proposal, by making one of the active nodes function as a token monitor to ensure against ring outage because of an erroneous token. Their proposal includes the capability for all nodes to become token monitors so that a single node failure does not affect ring operation. This gives the star-ring extremely good reliability.

Ring fault detection relies upon the topological structure (serial interconnection of nodes) to offer unique network management functions -- resilient topology and a purge mechanism. Recognition of the loss of a signal at its receiver by a node is signalled to all other downstream nodes

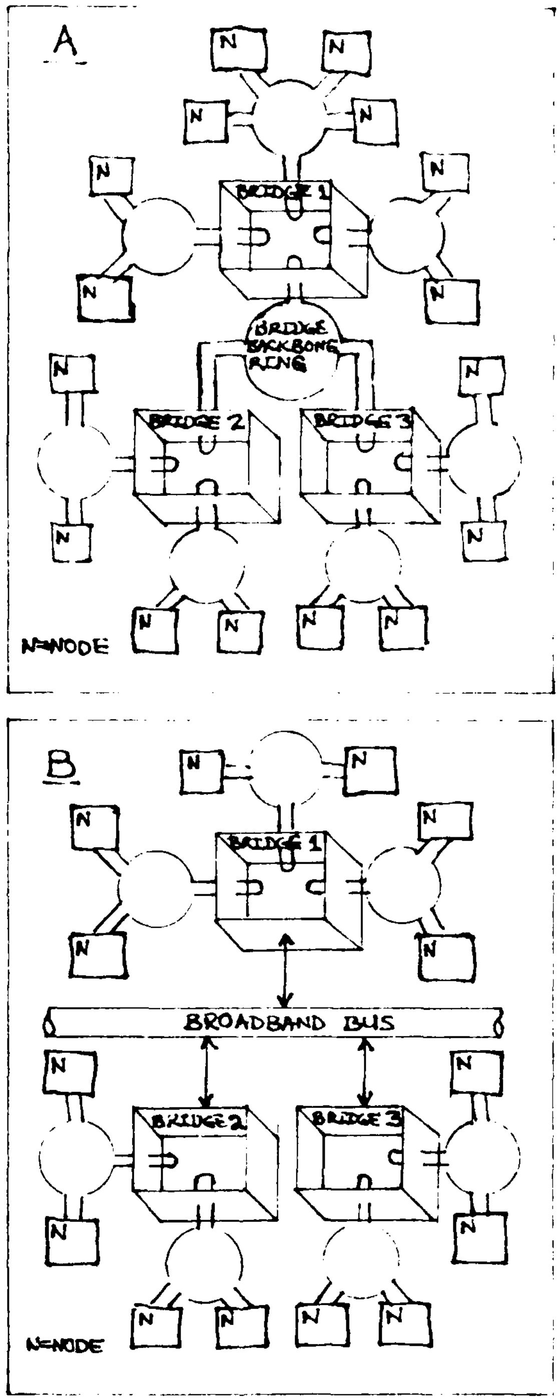

FIGURE 4-2: Multiple-bridge Local Area Network: (A) Token-ring Backbone, (B) Broadband-bus Backbone (2:51)

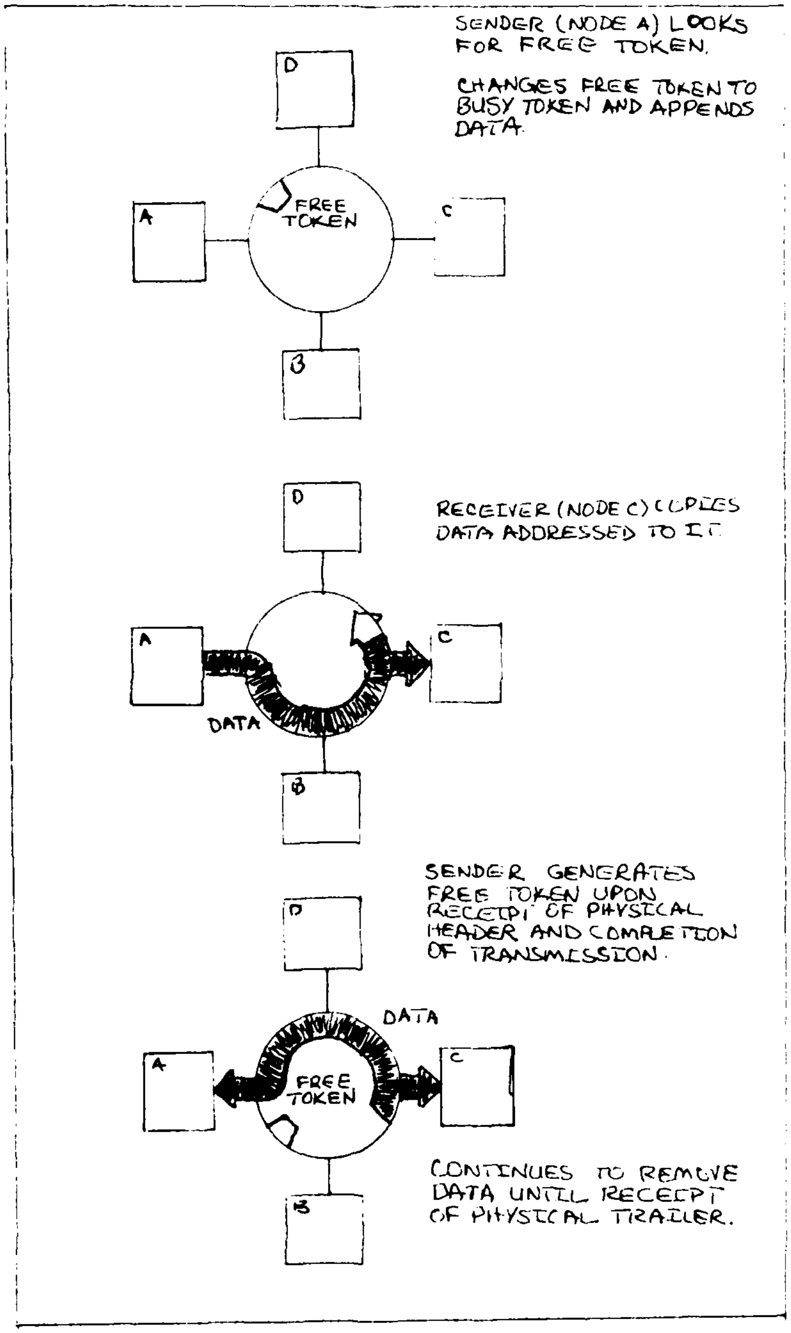

FIGURE 4-3: Ring with Token-access Control Protocol (2:57)

and this information is used to restore the integrity of the ring by reconfiguring the ring to bypass the break. Thus there is resiliency in the topology as opposed to being extremely vulnerable to single breaks occurring between nodes. The purge mechanism works by depending on the fact that each data frame must pass through each node on the link. Thus different types of control information can be propagated around the ring. "The resilient topology characteristic of a star-ring provides for efficient hard fault detection, whereas the ring purge mechanism provides for efficient soft fault detection." (2:59)

A hard fault (a complete break in a ring segment) causes the node adjacent to it to emit a unique frame sequence (beacon) thus identifying fault location. A soft fault is usually caused by a degradation in the electrical signal and is controlled by monitoring the traditional frame check sequence (FCS) included with each data frame on the wing. The first node that detects the error can set an indicator in the frame which isolates the problem to a particular ring segment. "Correlation of this information [error] with the source address contained within beacon-type frames or soft error report frames provides the required parameters to isolate the location of the fault." (2:60)

Reconfiguration of the ring segment interconnecting wiring concentrators is accomplished through the use of an alternate ring that runs parallel to the principal ring through all wiring concentrators (Figure 4-4). The signals on this alternate ring move in the opposite direction. Figure 4-4 shows that wrapping occurs between the principal and alternate rings when a fault exists between two wiring concentrators. This re-establishes a physical path around the ring within the same logical order. That is, Node N remains immediately downstream from Node M.

> The simple addition of an alternate ring path through each wiring concentrator provides a level of availability not readily apparent with other network topologies [bus]. This wrapping function, like the lobe bypass function, may be implemented with manual switches or automatic switching logic, or be command-initiated from a remote management facility. (2:61)

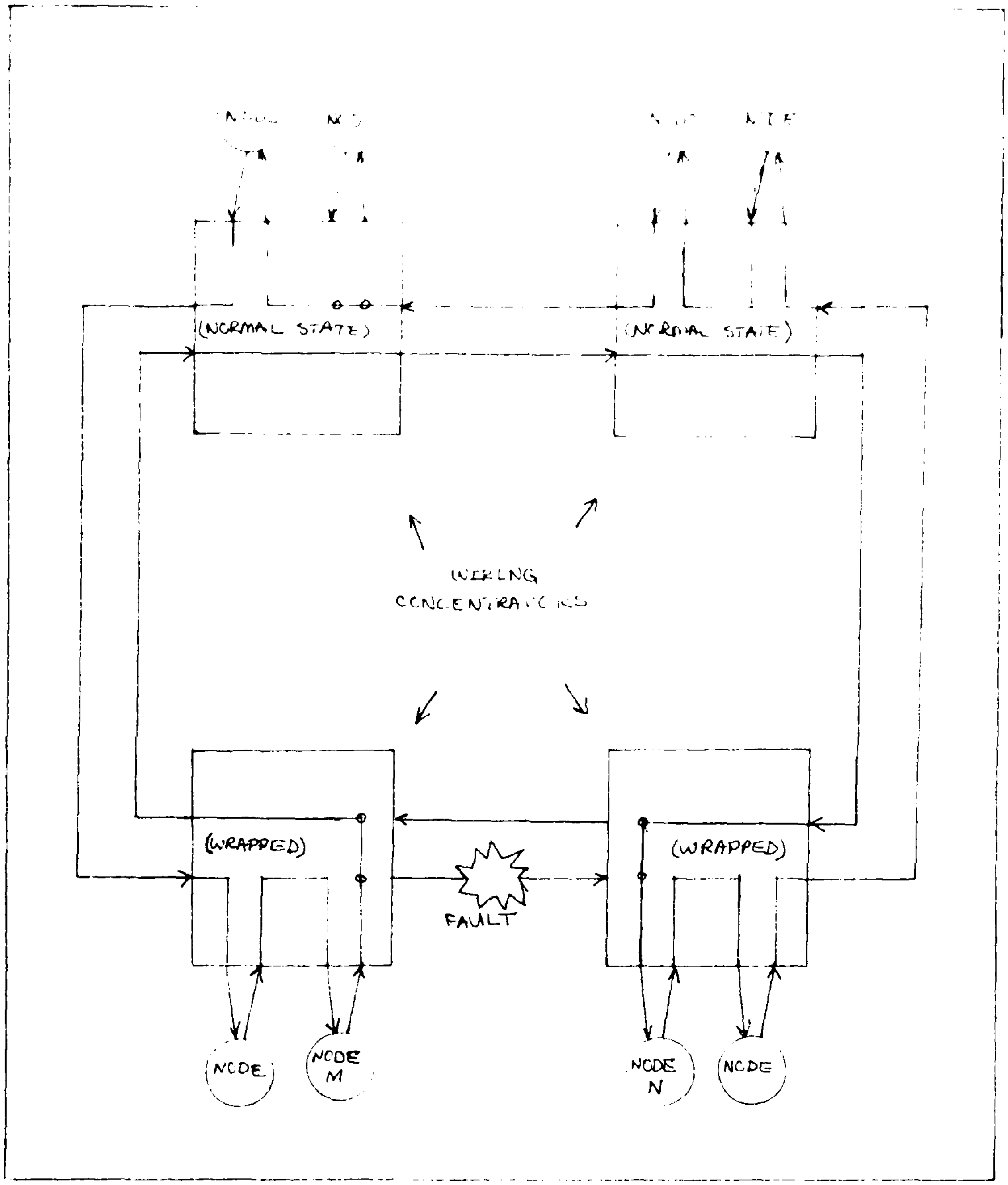

FIGURE 4-4: Ring Reconfiguration (after wrapping) (2:61)

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CHAPTER V

SUMMARY

Computers and the information explosion are having a tremendous effect on the Air Force's ability to efficiently and effectively handle the resulting data communications requirements. The forces for change are causing an acceleration in the growth of these data communications requirements. Local-area networks are a possible solution to the CONUS, non-secure, base-level data communications problems of the Air Force.

CONCLUSIONS

The pervasive use of computers in the Air Force and the information explosion has led to an increased data communications requirement. Complexity and the forces for change have placed increased demands on Air Force base-level data distribution systems. Any base-level data communications systems must be dynamic enough to handle the pace of change and rate of growth of Air Force future requirements.

FINDINGS

Two of the topological configurations for local-area networks -- mesh and star -- are too complex and expensive for base-level implementation. Of the bus and ring topologies, the ring provides the most potential reliability, expandability, and performance because of its inherent modularity and flexibility. The hybrid star-ring topological configuration advocated by IBM overcomes the disadvantages of the star and ring topologies.

RECOMMENDATION

The Air Force should install a prototype hybrid LAN as proposed by IBM for comparison with the current prototype bus LAN being installed at Gunter AFS, Alabama.

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